What does wood smell like?
Characterization of odorants in wood

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Abstract

Wood is a material humans come into contact with every day, e.g., in the form of furniture and building materials, products of daily use such as pencils and toys, or secondary products that are derived from wood such as paper and cardboard. Whereas general emissions of volatile organic compounds from wood are well known, only limited information is available on the odour-active substances. The present study therefore aimed at specifically elucidating the odorous constituents of wood. To gain an overview of the odorants emitted by wood, two different wood species were investigated.

Targeted odorant analysis requires specialized techniques combining modern odorant analytical tools with human-sensory evaluation. Following this concept, the wood samples were first evaluated by human sensory analysis. The odorants were then characterized by gas chromatography-olfactometry (GC-O) and ranked according to their odour potency via aroma extract dilution analysis (AEDA). Using this approach, more than 60 odorous substances were detected and the most potent odorants were identified by gas chromatography-mass spectrometry/olfactometry (GC-MS) and two-dimensional gas chromatography-mass spectrometry/olfactometry (2D-GC-MS/O).

Introduction

Previous investigations have predominantly focused on odorants in wood from wooden barrels that are used for wines and spirits, and their impact on the filling goods. Thus, mainly wood types with a potential usage in the alcoholic beverage production have previously been investigated and the samples were, according to their usage, commonly toasted. Following this conception, different oak woods as well as extracts from chestnut, acacia, cherry, and ash woods have already been analysed regarding their odorants.[1,2] In contrast to that, information about odorous substances in untreated wood, especially in softwoods, is rare. To close this gap, we focused on the elucidation of odorants in natural wood samples. Therefore, wood samples of incense cedar, which is commonly used for a range of products like pencils or furniture, and Scots pine, one of the most common trees in Germany, were investigated.

Experimental

Wood samples of incense cedar (*Calocedrus decurrens* (Torr.) Florin) and Scots pine (*Pinus sylvestris* L.) were supplied by Staedtler Mars GmbH & Co KG (Nuremberg, Germany). The samples were delivered in form of cuttings which were planed into wood shavings and were then directly used for analysis without any further treatment. The samples were analysed by a trained sensory panel prior to extraction to elaborate the respective odour profiles. For the isolation of the volatiles, 2.5 g of the wood shavings were mixed with 100 ml dichloromethane. The solution was stirred at room temperature for 30 min and thereafter immediately applied for solvent assisted flavour evaporation

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(SAFE) [3]. Aroma extract dilution analysis (AEDA) [4] was performed using GC-O [5]. The most potent odour-active compounds were identified using GC-MS/O and 2D-GC-MS/O by comparing the odour quality, linear retention index [6], and mass spectrum with the properties of the respective reference compounds. Experimental details for the sensory evaluation as well as the instrumental analysis were as described in Schreiner et al. 2017 [5].

Results and discussion

The odour profile analyses (cf. figure 1) showed that the smell of the incense cedar wood sample was dominated by a pencil-like note showing the highest intensity (5.2) followed by a sawdust-like odour impression (2.9). In contrast to that, the Scots pine wood sample smelled strongly resin-like with an intensity of 7.1 followed by sawdust-like (2.7) and frankincense-like notes (2.6). AEDA showed 16 substances to be the most potent odorants in Scots pine wood or incense cedar wood, respectively, with flavour dilution (FD) factors of ≥729 (cf. table 1). 14 of these substances were successfully identified. Most of the odour-active compounds are commonly known fatty acid degradation products like unsaturated alkenals and dialkenals with fatty smells, or acids like butanoic and heptanoic acid. Moreover, a group of terpenoic substances was found, *inter alia* the woody, resinous smelling α-pinene or α-bisabolol (balsamic, peppery). Another prominent group of odour-active constituents in both wood types were phenyl compounds such as vanillin or p-cresol, occurring due to the degradation of lignin. Two substances with a sweaty, perfume-like, androstenone-like smell remained unknown in the cedar samples, but could be tentatively identified in the pine wood samples as androst-2,16-diene and (5β)-androst-2-en-17-one.

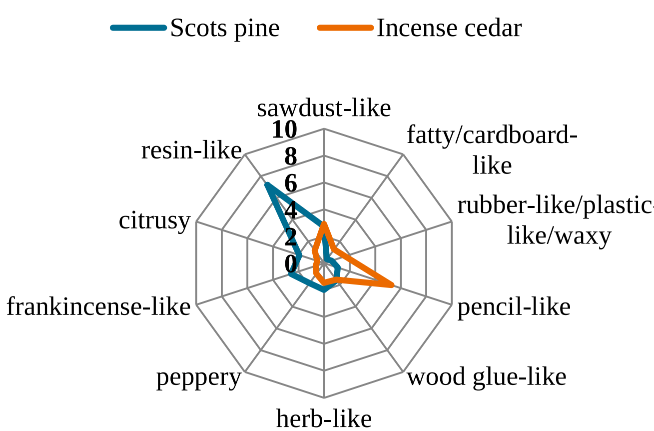

Figure 1: Odour profiles of Incense cedar and Scots pine wood

The results of the sensory evaluation show a close agreement with the odour qualities of the identified odorants. The most potent attribute for the Scots pine wood was resin-like which could be correlated with α-pinene, whereas the main attribute chosen to describe the smell of the incense cedar was pencil-like. This smell impression appears to result from the pronounced smell impact associated with thymoquinone. Thymoquinone as naturally occurring molecule with a pencil-like smell was a new finding [5]. Thymoquinone is known to be the major compound in black cumin seed (*Nigella sativa* L.) [7] and contributes with its bioactivity for example to the antioxidant [8] and anti-inflammatory [9] activities of black cumin seed essential oil.

Table 1: Odorant compounds, their retention indices, flavour dilution (FD) factors, and odour qualities as identified in incense cedar and Scots pine wood

Substance	*Odour quality*	*RI DB-FFAP*		*FD-factor*	
		Incense cedar	*Scots pine*	*Incense cedar*	*Scots pine*
α-Pinene	woody, resinous	1029	1032	≥ 729	≥ 729
(*E*)-Non-2-enal	fatty	1533	1526	≥ 729	243
3-Methylbutanoic acid	cheesy	1664	1677	≥ 729	9
(*E*,*E*)-Nona-2,4-dienal	fatty	1700	1700	≥ 729	≥ 729
(*E*,*E*)-Deca-2,4-dienal	fatty	1810	1810	81	≥ 729
Heptanoic acid	red pepper-like, plastic-like	n.d.	1942	n.d.	≥ 729
δ-Octalactone	coconut-like	1920	1984		≥ 729
p-Cresol	horse-like	2100	2089	≥ 729	27
Sotolone	savoury	2222	2212	≥ 729	243
α-Bisabolol	blasamic, peppery	2250	2255	≥ 729	9
Phenylacetic acid	honey-like	2563	2567	243	≥ 729
Vanillin	vanilla-like	2588	2594	≥ 729	≥ 729
3-Phenylpropanoic acid	metallic, fruity, vomit-like	2625	2640	≥ 729	≥ 729
(5β)-Androst-2-en-17-one[1]	sweaty, perfume-like, androstenone-like	2875	2878	≥ 729	81
Androst-2,16-diene[1]	sweaty, perfume-like, androstenone-like	2986	2927	≥ 729	27
Thymoquinone	pencil-like	3100	3100	243	≥ 729

[1] tentatively identified

Additionally, it was the first time that 3-phenylpropanoic acid, hexanoic acid, α-bisabolol, and thymoquinone are reported to be odour-active substances in wood. α-Bisabolol is a sesquiterpene which was first found in German chamomile (*Matricaria chamomilla*) [10]. It has already been discovered as ingredient in the oil from Candeia wood (*Eremanthus erythropappus*) [11], but its appearance as wood odorant is a new finding. Whereas thymoquinone and α-bisabolol are naturally occurring molecules, hexanoic acid and 3-phenylpropanoic acid are likely to result from degradation of common wood components such as fatty acids and lignin.

Quantification trials will be a future challenge to trace back the differences in smell between the respective wood samples, as the respective profiles indicate that most likely the sensory differences result from quantitative rather than general qualitative differences in odorant composition. Moreover, more comprehensive investigations will be required targeting the impact of wood smell on wellbeing in humans.

Conclusions

The found odorants belong to a variety of substance classes and exhibit a great diversity in odour character. Some of the substances are known constituents in wood whereas others were identified for the first time in wood or even for the first time as being odour-active. The successful elucidation of potent odorants in wood is a first important step towards the understanding of the molecular basis of the odour profile of a commonly-used material in daily life.

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